Decision Support Systems (DSS)

Definition

The concept of DSS is extremely broad, and its definitions vary, depending on the author's point of view.

1. **Decision Supports Systems (DSS**) are computer-based information systems designed in such a way that help managers to select one of the many alternative solutions to a problem. It is possible to automate some of the decision making processes in a large, computer-based DSS which is sophisticated and analyze huge amount of information fast. It helps corporate to increase market share, reduce costs, increase profitability and enhance quality. The nature of problem itself plays the main role in a process of decision making. A DSS is an interactive computer based information system with an organized collection of models, people, procedures, software, databases, telecommunication, and devices, which helps decision makers to solve unstructured or semi-structured business problems.

2. Computer system designed to provide assistance in determining and evaluating alternative courses of action. A DSS (1) acquires data from the mass of routine transactions of a firm, (2) analyzes it with advanced statistical techniques to extract meaningful information, and (3) narrows down the range of choices by applying rules based on decision theory. Its objective is facilitation of 'what if' analysis and not replacement of a manager's judgment.

3. A decision support system (DSS) is a computer program application that analyzes business data and presents it so that users can make business decisions more easily. It is an "informational application" (to distinguish it from an "operational application" that collects the data in the course of normal business operation).

Evolution History of DSS is illustrated in Fig.1 below:

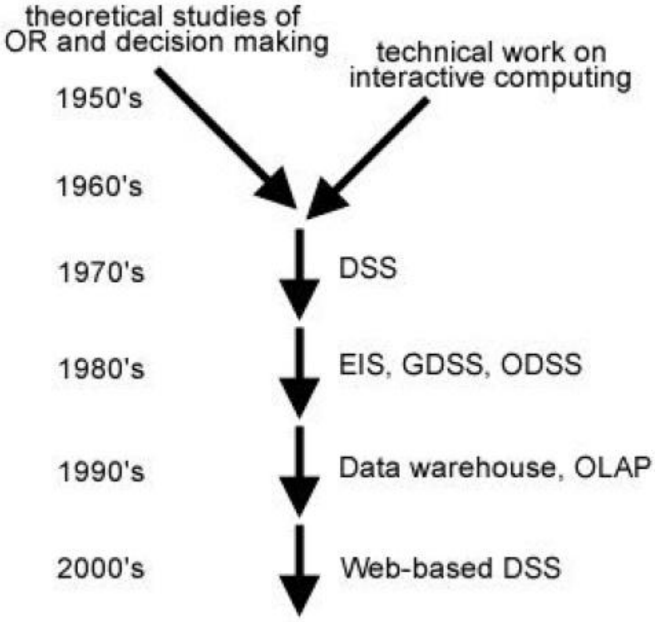

Figure 1. A brief history of DSS

Executive Information Systems **(EIS**), Group Decision Support Systems (**GDSS**), and Organizational Decision Support Systems (**ODSS**) evolved from the single user and model oriented DSS. Beginning in about 1990, data warehousing and On-Line Analytical Processing **(OLAP**) began broadening the realm of DSS.

What is the need for decision support?

Today, decision making is more difficult. The need for decision-making speed has increased, overload of information is common, and there is more distortion of information. On the positive side, there is a greater emphasis on fact-based decision making. A complex decision-making environment creates a need for computerized decision support. Research and case studies provide evidence that a well-designed and appropriate computerized decision support system can encourage fact-based decisions, improve decision quality, and improve the efficiency and effectiveness of decision processes.

Most managers want more analyses and specific decision-relevant reports quickly. Certainly, we have many and increasing information needs. The goal of DSS is to create and use better information. Today, there is a pressing need to use technology to help make important decisions. Decision makers perform better with the right information at the right time. In general, computerized decision support can help transfer and organize knowledge. Effective decision support provides managers more independence to retrieve and analyze data and documents to obtain facts and results, as they need them.

From a different perspective, cognitive decision-making biases exist and create a need for decision support. Information presentation and information availability influence decision makers both positively and negatively. Reducing bias has been a secondary motivation for building DSS. Most managers accept that some people are biased decision makers but often question if a proposed DSS will reduce bias. For example, decision makers “anchor” on the initial information they receive and that influences how they interpret subsequent information. In addition, decision makers tend to place the greatest attention on more recent information and either ignore or forget historical information.

Changing decision-making environments, managerial requests, and decision-maker limitations creates a need for more and better decision support. We should consider building a computerized decision support system when (a) good information is likely to improve the quality of decisions and (b) potential DSS users recognize a need for and want to use computerized support.

Introducing more and better decision support in an organization does create changes and challenges for managers. Using a smart phone with decision support applications or a Tablet PC with wireless connectivity to the Internet and corporate databases requires new skills and new knowledge.

What technology skills do managers need?

Technology skills quickly become obsolete. Concepts and theory have a much longer “shelf life.” DSS use reasonably sophisticated information hardware and software technologies, so you need computing and software knowledge to understand such systems. In addition, you need technology skills because you may need to provide input to hardware and software choices. At a minimum in today's business environment, you need to be able to operate the software environment of your

personal computing devices (e.g., a workstation, a portable computer, or a Smartphone (Mobiles), Smart Pad (iPad….etc)…).

Your software environment is rapidly changing (i.e., new versions of Microsoft Office, new Google products, and new intra-company Web-based applications are constantly on the rise). In addition, you need to master software products relevant to your job. In some situations, you may develop small-scale budgeting or cost-estimating applications in Excel or a product like Crystal Reports. There is a growing need for “end user” development of small-scale DSS and preparation of special decision support studies.

Networks and enterprise-wide global systems are expanding. Because managers and knowledge workers are the primary users of enterprise-wide decision support systems, managers must understand the possibilities and be involved in designing the systems.

For many reasons, all managers need to understand the upside benefits and the downside risks of building a specific decision support capability. Decision support systems can solve problems and create new problems. In addition, as a manager, you need to help make informed decision support design, development, and implementation choices.

DSS, computing, and information technology (IT) knowledge and skill needs are constantly evolving. We all need to learn new concepts and new skills. Some new requirements build on previously learned materials; others force us to change dramatically and to “un” learn what we had learned.

What Is the Theory of Computerized Decision Support Systems?

Past practice and experience often guide computerized decision support development more than theory and general principles. Some developers say each situation is different so no theory is possible. Others argue that we have conducted insufficient research to develop theories. For these reasons, the theory of decision support and DSS has not been addressed extensively in the literature.

The following set of six propositions from the writings of the late Nobel Laureate Economist Herbert Simon form an initial theory of decision support. From Simon’s classic book, *Administrative Behavior*, we draw three propositions.

Proposition 1: If information stored in computers is accessible when needed for making a decision, it can increase human rationality.

Proposition 2: Specialization of decision-making functions is largely dependent upon developing adequate channels of communication to and from decision centers.

Proposition 3: When a particular item of knowledge is needed repeatedly in decision making, an organization can anticipate this need and, by providing the individual with this knowledge prior to decision, can extend his or her area of rationality. Providing this knowledge is particularly important when there are time limits on decisions.

From Simon's article 18 on "Applying Information Technology to Organization Design," we identify three additional propositions:

Proposition 4: In the post-industrial society, the central problem is not how to organize to produce efficiently but how to organize to make decisions – that is, to process information. Improving efficiency will always remain an important consideration.

Proposition 5: From the information processing point of view, division of labor means factoring the total system of decisions that need to be made into relatively independent subsystems, each one of which can be designed with only minimal concern for its interactions with the others.

Proposition 6: The key to the successful design of information systems lies in matching the technology to the limits of the attention of users. In general, an additional component, person, or machine for an information-processing system will improve the system's performance when the following three conditions are true:

1. The component's output is small in comparison with its input so that it conserves attention instead of making additional demands on attention.

2. The component incorporates effective indexes of both passive and active kinds. Active indexes automatically select and filter information.

3. The component incorporates analytic and synthetic models that are capable of solving problems, evaluating solutions, and making decisions.

In summary, computerized decision support is potentially desirable and useful when there is a high likelihood of providing relevant, high quality information to decision makers when they need it and want it.

What Is Different About Modern Decision Support Systems?

The modern era in decision support systems started in about 1995 with the specification of HTML 2.0, the expansion of the World Wide Web in companies, and the introduction of handheld computing. Today, the Web 2.0 technologies, mobile-integrated communication and computing devices, and improved software development tools have revolutionized DSS user interfaces. Additionally, the decision support data store back-end is now capable of rapidly processing very large data sets.

Modern DSS are more complex and more diverse in functionality than DSS built prior to the widespread use of the World Wide Web. Today, we are seeing more decision automation with business rules and more knowledge-driven decision support systems. Current DSS are changing the mix of decision-making skills needed in organizations. Building better DSS may provide one of the "keys" to competing in a global business environment.

The following attributes are increasingly common in new and updated decision support systems. Some attributes are more closely associated with one category of DSS, but sophisticated DSS often have multiple subsystems. **Attributes of contemporary DSS** include the following:

1. Multiple, remote users can collaborate in real-time using rich media.

2. Users can access DSS applications anywhere and anytime.

3. Users have fast access to historical data stored in very large data sets.

4. Users can view data and results visually with excellent graphs and charts.

5. Users can receive real-time data when needed.

Decisions and Decision Modeling

Types of Decisions

A simple view of decision making is that it is a problem of choice among several alternatives. A somewhat more sophisticated view includes the process of constructing the alternatives (i.e., given a problem statement, developing a list of choice options). A complete picture includes a search for opportunities for decisions (i.e., discovering that there is a decision to be made). A manager of a company may face a choice in which the options are clear (e.g., the choice of a supplier from among all existing suppliers). She may also face a well-defined problem for which she designs creative decision options (e.g., how to market a new product so that the profits are maximized). Finally, she may work in a less reactive fashion and view decision problems as opportunities that have to be discovered by studying the operations of her company and its surrounding environment (e.g., how can she make the production process more efficient). There is much anecdotal and some empirical evidence that structuring decision problems and identifying creative decision alternatives determine the ultimate quality of decisions. Decision support systems aim mainly at this broadest type of decision making, and in addition to supporting choice, they aid in modeling and analyzing systems (such as complex organizations), identifying decision opportunities, and structuring decision problems.

Human Judgment and Decision Making

Theoretical studies on rational decision making, notably that in the context of probability theory and decision theory, have been accompanied by empirical research on whether human behavior complies with the theory. It has been rather convincingly demonstrated in numerous empirical studies that human judgment and decision making is based on intuitive strategies as opposed to theoretically sound reasoning rules. These intuitive strategies, referred to as judgmental heuristics in the context of decision making, help us in reducing the cognitive load, but alas at the expense of optimal decision making. Effectively, our unaided judgment and choice exhibit systematic violations of probability.

One might hope that people who have achieved expertise in a domain will not be subject to judgmental biases and will approach optimality in decision making. While empirical evidence shows that experts indeed are more accurate than novices within their area of expertise, it also shows that they also are liable to the same judgmental biases as novices and demonstrate apparent errors and inconsistencies in their judgment. Professionals such as practicing physicians use essentially the same judgmental heuristics and are prone to the same biases, although the degree of departure from the normatively prescribed judgment seems to decrease with experience. In addition to laboratory evidence, there are several studies of expert performance in realistic settings, showing that it is inferior even to simple linear models (an informal review of the available evidence and pointers to literature can be found in the book by Dawes). For example, predictions of future violent behavior of psychiatric patients made by a panel of psychiatrists who had access to patient records and interviewed the patients were found to be inferior to a simple model that included only the past incidence of violent behavior. Predictions of marriage counselors concerning marital happiness were shown to be inferior to a simple model that just subtracted the rate of fighting from the rate of sexual intercourse (again, the marriage counselors had access to all data, including interviews with the couples). Studies yielding similar results have been conducted with bank loan officers, physicians, university admission committees, and so on.

DSS Applications and Components

Typical application areas of DSSs are management and planning in business, health care, the military, and any area in which management will encounter complex decision situations. Decision support systems are typically used for strategic and tactical decisions faced by upper-level management decisions with a reasonably low frequency and high potential consequences in which the time taken for thinking through and modeling the problem pays off generously in the long run.

There are three fundamental **components** of DSSs:

- Database management system (DBMS). A DBMS serves as a data bank for the DSS. It stores large quantities of data that are relevant to the class of problems for which the DSS has been designed and provides logical data structures (as opposed to the physical data structures) with which the users interact. A DBMS separates the users from the physical aspects of the database structure and processing. It should also be capable of informing the user of the types of data that are available and how to gain access to them.

- Model-base management system (MBMS). The role of MBMS is analogous to that of a DBMS. Its primary function is providing independence between specific models that are used in a DSS from the applications that use them. The purpose of an MBMS is to transform data from the DBMS into information that is useful in decision making. Since many problems that the user of a DSS will cope with may be unstructured, the MBMS should also be capable of assisting the user in model building.

- Dialog generation and management system (DGMS). The main product of an interaction with a DSS is insight. As their users are often managers who are

not computer-trained, DSSs need to be equipped with intuitive and easy-to-use interfaces. These interfaces aid in model building, but also in interaction with the model, such as gaining insight and recommendations from it. The primary responsibility of a DGMS is to enhance the ability of the system user to utilize and benefit from the DSS. In the remainder of this article, we will use the broader term user interface rather than DGMS.

Interaction among these three components is illustrated in (Fig.1)…Essentially; the user interacts with the DSS through the DGMS. This communicates with the DBMS and MBMS, which screen the user and the user interface from the physical details of the model base and database implementation.

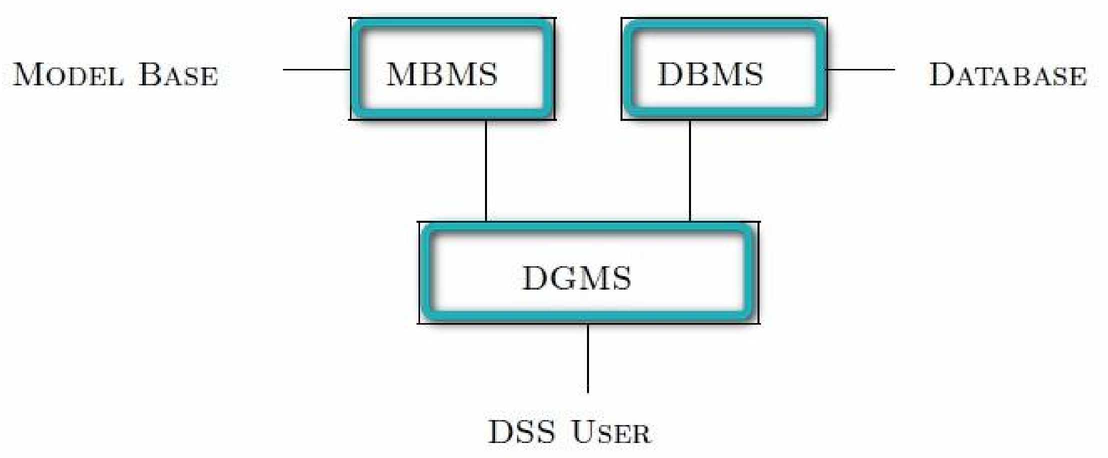

Figure 1: The architecture of a DSSs

Normative Systems

Normative and Descriptive Approaches

There are two distinct approaches to supporting decision making.

The **First** aims at building support procedures or systems that imitate human experts. The most prominent member of this class of DSSs are expert systems, computer programs based on rules elicited from human domain experts that imitate reasoning of a human expert in a given domain. Expert systems are often capable of supporting decision making in that domain at a level comparable to human experts. While they are flexible and often able to address complex decision problems, they are based on intuitive human reasoning and lack soundness and formal guarantees with respect to the theoretical reliability of their results. The danger of the expert system approach, increasingly appreciated by DSS builders, is that along with imitating human thinking and its efficient heuristic principles, we may also imitate its undesirable flaws.

The **Second** approach is based on the assumption that the most reliable method of dealing with complex decisions is through a small set of normatively sound principles of how decisions should be made. While heuristic methods and ad hoc reasoning schemes that imitate human cognition may in many domains perform well, most decision makers will be reluctant to rely on them whenever the cost of making an

error is high. To give an extreme example, few people would choose to fly airplanes built using heuristic principles over airplanes built using the laws of aerodynamics enhanced with probabilistic reliability analysis. Application of formal methods in DSSs makes these systems philosophically distinct from those based on ad hoc heuristic artificial intelligence methods, such as rule-based systems. The goal of a DSS, according to this view, is to support unaided human intuition, just as the goal of using a calculator is to aid human's limited capacity for mental arithmetic.

Decision-Analytic Decision Support Systems

An emergent class of DSSs known as decision-analytic DSSs applies the principles of **decision theory**, **probability theory**, and **decision analysis** to their decision models.

Decision theory is an axiomatic theory of decision making that is built on a small set of axioms of rational decision making. It expresses uncertainty in terms of probabilities and preferences in terms of utilities. These are combined using the operation of mathematical expectation.
The attractiveness **of probability theory**, as formalism for handling uncertainty in DSSs, lies in its soundness and its guarantees concerning long-term performance. Probability theory is often viewed as the gold standard for rationality in reasoning under uncertainty. Following its axioms offers protection from some elementary inconsistencies.
Decision analysis is the art and science of applying decision theory to real-world problems. It includes a wealth of techniques for model construction, such as methods for elicitation of model structure and probability distributions that allow minimization of human bias, methods for checking the sensitivity of a model to imprecision in the data, computing the value of obtaining additional information, and presentation of results.

Decision-analytic DSSs have been successfully applied to practical systems in medicine, business, and engineering.

User Interfaces to Decision Support Systems

While the quality and reliability of modeling tools and the internal architectures of DSSs are important, the most crucial aspect of DSSs is, by far, their user interface. Systems with user interfaces that are cumbersome or unclear or that require unusual skills are rarely useful and accepted in practice. The most important result of a session with a DSS is insight into the decision problem. In addition, when the system is based on normative principles, it can play a tutoring role; one might hope that users will learn the domain model and how to reason with it over time, and improve their own thinking.
A good user interface to DSSs should support model construction and model analysis, reasoning about the problem structure in addition to numerical calculations and both choice and optimization of decision variables. We will discuss these in the following sections.

Support for Model Construction and Model Analysis

User interface is the vehicle for both model construction (and model choice) and for investigating the results. Even if a system is based on a theoretically sound reasoning scheme, its recommendations will be as good as the model they are based on. Furthermore, even if the model is a very good approximation of reality and its recommendations are correct, they will not be followed if they are not understood. Without understanding, the users may accept or reject a system's advice for the wrong reasons and the combined decision-making performance may deteriorate even below unaided performance. A good user interface should make the model on which the system's reasoning is based transparent to the user.

Modeling is rarely a one-shot process, and good models are usually refined and enhanced as their users gather practical experiences with the system recommendations. It is important to strike a careful balance between precision and modeling efforts; some parts of a model need to be very precise while others do not. A good user interface should include tools for examining the model and identifying its most sensitive parts, which can be subsequently elaborated on. Systems employed in practice will need their models refined, and a good user interface should make it easy to access, examine, and refine its models.

Support for Reasoning about the Problem Structure in Addition to Numerical Calculations

While numerical calculations are important in decision support, reasoning about the problem structure is even more important. Often when the system and its model are complex it is insightful for the decision maker to realize how the system variables are interrelated. This is helpful in designing creative decision options but also in understanding how a policy decision will impact the objective.
Graphical models, such as those used in decision analysis or in equation-based and hybrid systems, are particularly suitable for reasoning about structure. Under certain assumptions, a directed graphical model can be given a causal interpretation. This is especially convenient in situations where the DSS suggests decision options; given a causal interpretation of its model, it is capable of predicting effects of interventions. A causal graph facilitates building an effective user interface. The system can refer to causal interactions during its dialogue with the user, which is known to enhance user insight.

Support for Both Choice and Optimization of Decision Variables

Many DSSs have an inflexible structure in the sense that the variables that will be manipulated are determined at the model-building stage. This is not very suitable for planning of the strategic type when the object of the decision-making process is identifying both the objectives and the methods of achieving them. For example, changing policy variables in a spreadsheet-based model often requires that the entire spreadsheet be rebuilt. If there is no support for that, few users will consider it as an option. This closes the world of possibilities for flexible reframing of a decision problem in the exploratory process of searching for opportunities. Support for both choice and optimization of decision variables should be an inherent part of DSSs.

Graphical Interface

Insight into a model can be increased greatly at the user interface level by a diagram representing the interactions among its components; for example, a drawing of a graph on which a model is based. This graph is a qualitative, structural explanation of how information flows from the independent variables to the dependent variables of interest. As models may become very large, it is convenient to structure them into submodels, groups of variables that form a subsystem of the modeled system. Such submodels can be again shown graphically with interactions among them, increasing simplicity and clarity of the interface. Fig. 2 shows a submodel-level view of a model developed in our ESP project.

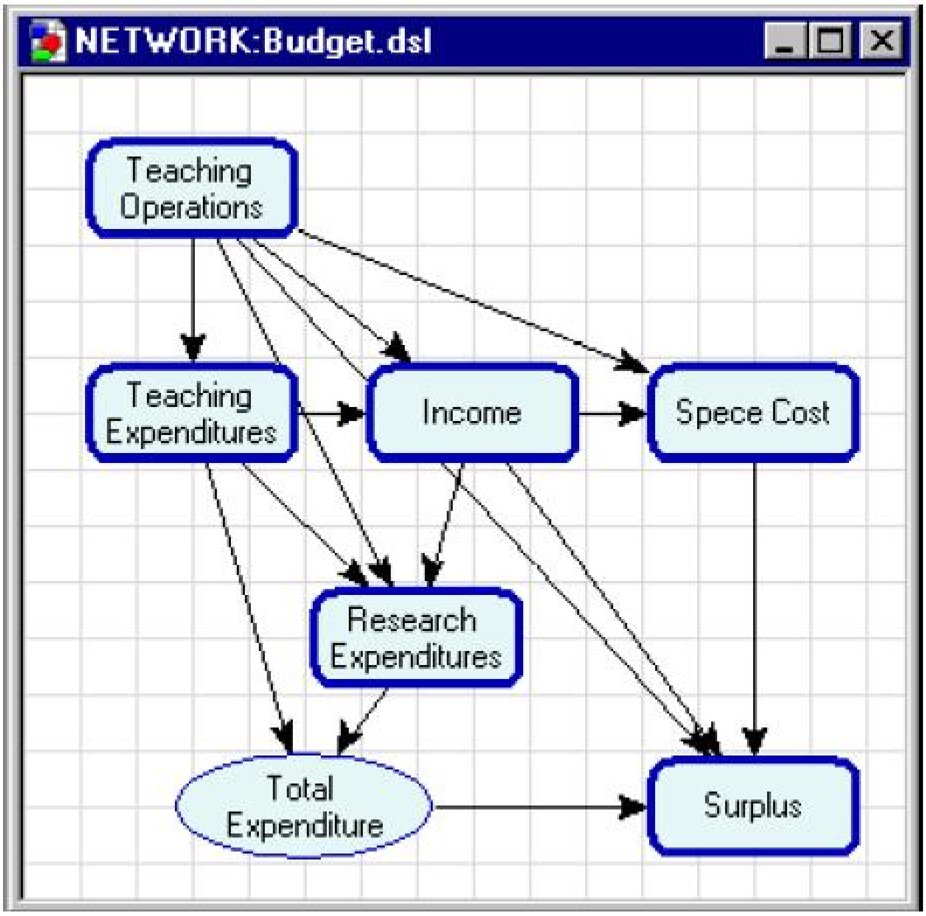

Figure 2: A submodel-level view of a decision model.